Chapter 02 Lecture Outline*

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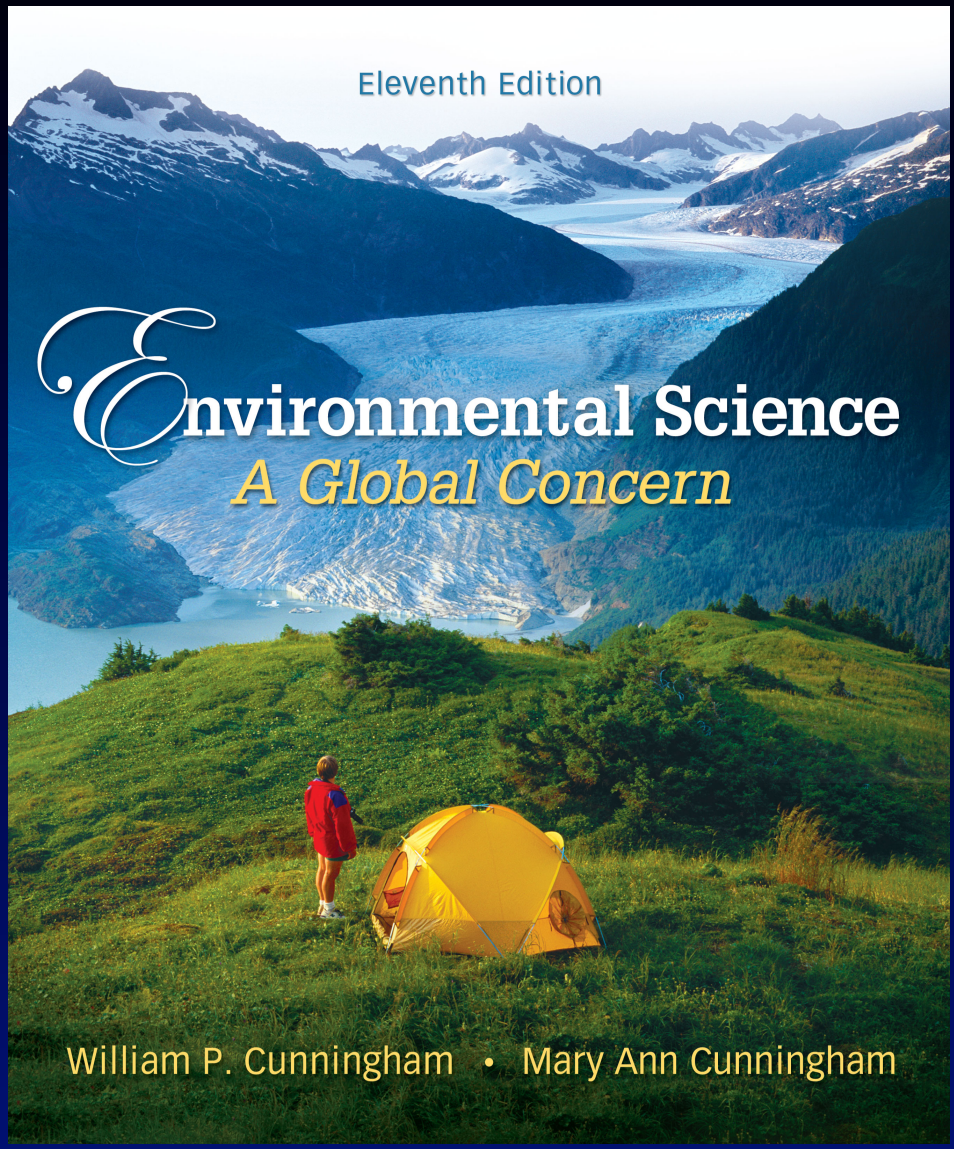

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Principles of Science and Systems

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Courtesy of David Tilman

Outline

- What is Science?
- Variables and Experimental Design
- Models and Systems
- Consensus and Conflict in Science
- Recognizing Pseudoscience
- Environmental Science vs. Environmentalism

What is Science?

Science is:

- a methodical, logical process for producing knowledge about natural phenomena
- a cumulative body of knowledge produced by scientists
- a process based on careful observation and hypothesis testing

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TABLE 2.1

Basic Principles of Science

1. *Empiricism:* We can learn about the world by careful observation of empirical (real, observable) phenomena; we can expect to understand fundamental processes and natural laws by observation.
2. *Uniformitarianism:* Basic patterns and processes are uniform across time and space; the forces at work today are the same as those that shaped the world in the past, and they will continue to do so in the future.
3. *Parsimony:* When two plausible explanations are reasonable, the simpler (more parsimonious) one is preferable. This rule is also known as Ockham's razor, after the English philosopher who proposed it.
4. *Uncertainty:* Knowledge changes as new evidence appears, and explanations (theories) change with new evidence. Theories based on current evidence should be tested on additional evidence, with the understanding that new data may disprove the best theories.
5. *Repeatability:* Tests and experiments should be repeatable; if the same results cannot be reproduced, then the conclusions are probably incorrect.
6. *Proof is elusive:* We rarely expect science to provide absolute proof that a theory is correct, because new evidence may always undermine our current understanding.
7. *Testable questions:* To find out whether a theory is correct, it must be tested; we formulate testable statements (hypotheses) to test theories.

Science Depends on Skepticism and Accuracy

- Ideally scientists are skeptical and unbiased.
- Scientists strive for:
  - accuracy - correctness of measurements
  - reproducibility - repeatability of results
    - Repeating studies or tests is called replication.

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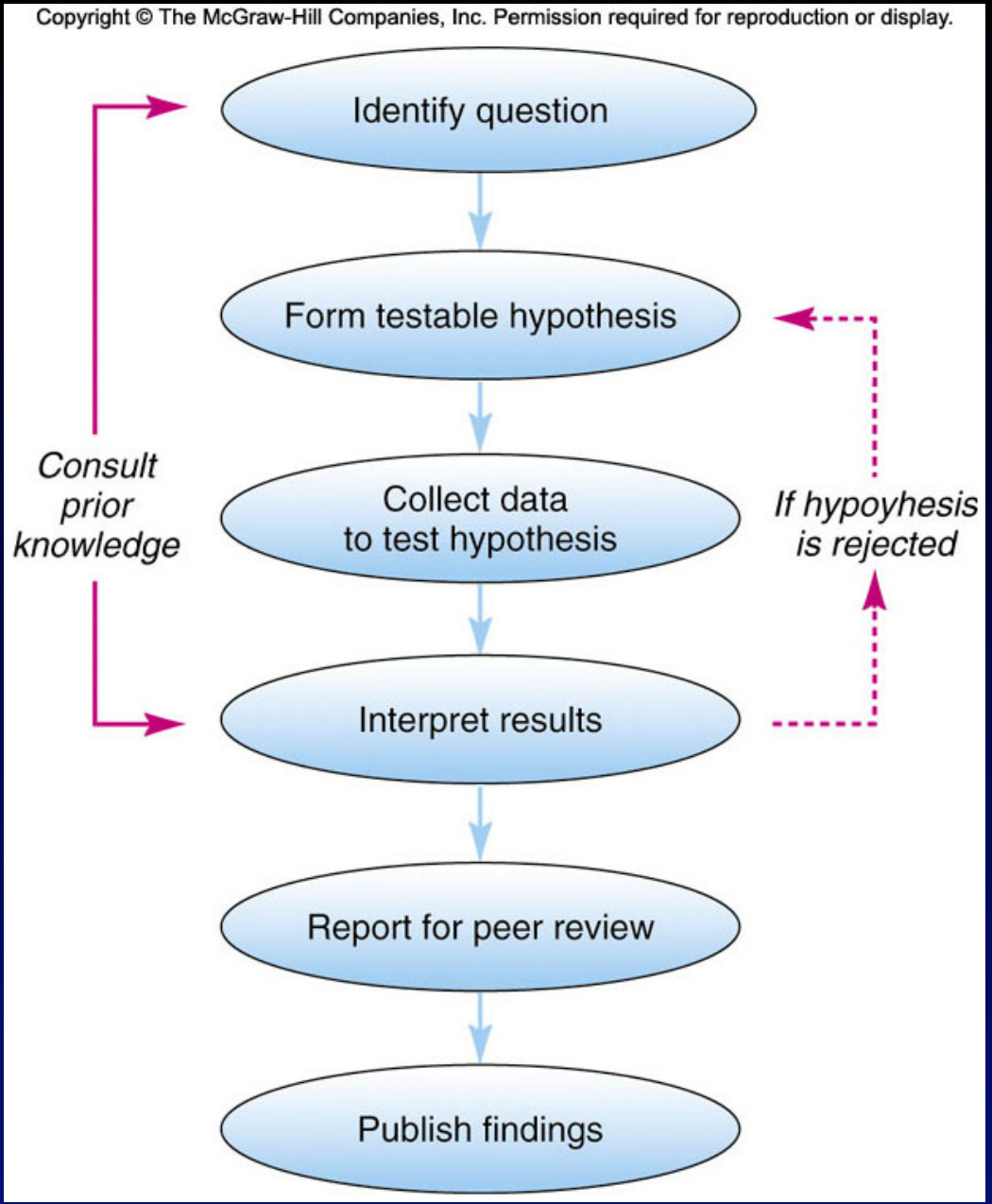


Deductive & Inductive Reasoning

- Deductive reasoning - logical reasoning from general to specific
- Inductive reasoning - reasoning from many observations to produce a general rule
- It is also important to recognize the role of insight, creativity, aesthetics, and luck in research.

Hypotheses and Theories

- Hypothesis - a testable explanation
- Scientific theory - a description or explanation that has been supported by a large number of tests and is considered by experts to be reliable

Probability

- Probability is a measure of how likely something is to occur.
- Scientists often increase confidence in a study by comparing results to a random sample or a larger group.

Statistics

- Many statistical tests focus on calculating the probability that observed results could have occurred by chance.
- Usually ecological tests are considered significant if this probability is less than 5%.
- The amount of confidence scientists have in the results depends upon the sample size as well. A large sample size is better than a small sample.

Experimental Design

- Natural experiment - involves observation of events that have already happened
- Manipulative experiment - conditions are deliberately altered for one variable and all other variables are held constant
- Controlled study - comparing a treatment group to a control group which has not received the treatment
- Blind experiment - researcher doesn't know which group has been treated until after the data have been analyzed
- Double-blind experiment - neither the subject nor the researcher knows who is in the treatment group

Variables

- In each study there is one dependent variable and one or more independent variables.
- The dependent variable is affected by what happens to the independent variable.
- In a graph, the dependent variable is on the vertical (Y) axis and the independent variable is on the horizontal axis (X).

Models

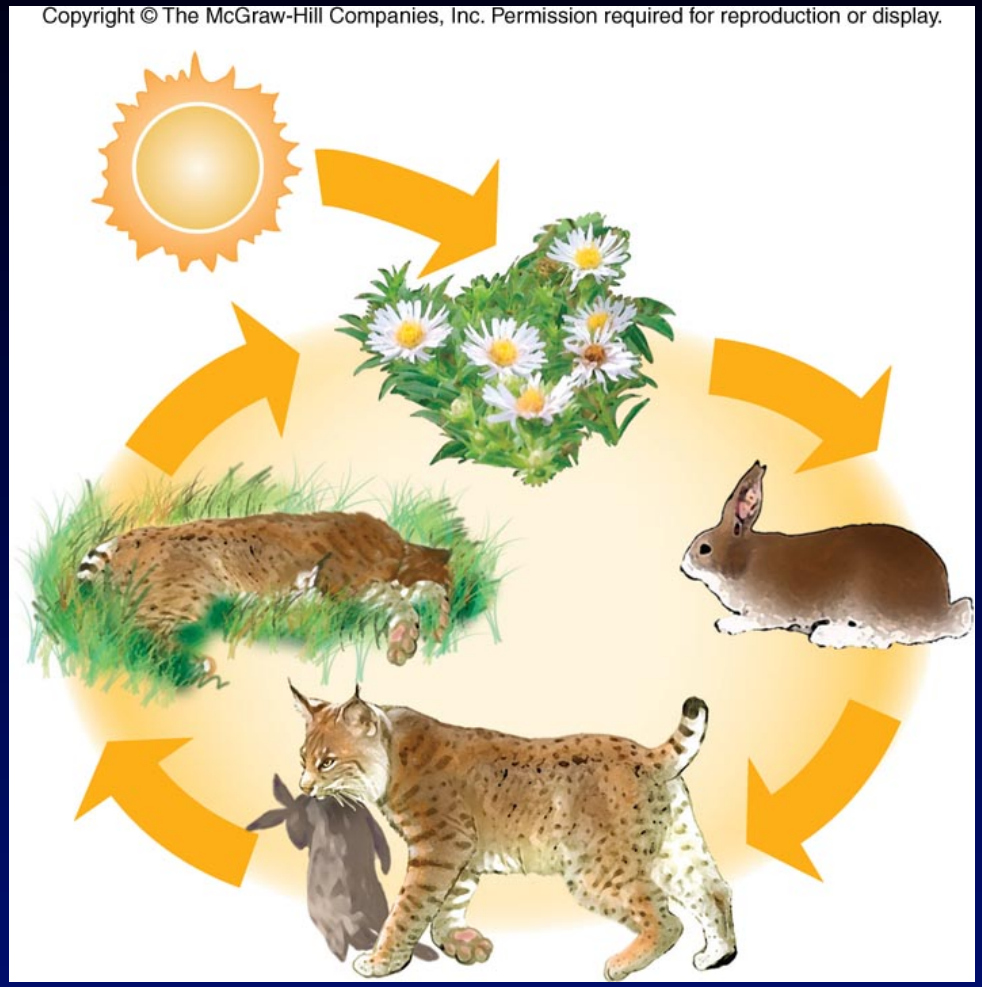
- Models are simple representations of phenomena. They can be physical models, model organisms, mathematical models, or other types of models.
- They allow scientists to study complex systems and predict the effect of conditions that are too difficult to create and control.
- When multiple models agree, scientists gain confidence.

Systems

- Systems - networks of interdependent components and processes with materials and energy flowing from one component to another.
- Systems are a central concept in environmental science.
- Examples: ecosystems, climates systems, geologic systems, economic systems

Components of a System

- State Variables: store resources such as matter or energy or have the pathways through which these resources move from one state variable to another (ie. The plant and the animals in Fig. 2.9 are each state variables).



System Characteristics

- A System can be closed or open.
  - Closed - self contained and receives no inputs of energy or materials from the outside
  - Open - system that takes inputs from its surroundings
- Throughput –the energy and matter that flow into, through and out of a system.
- Positive feedback loop - when a flow leads to compartment changes that further enhance the flow
- Negative feedback loop - dampens flow

Stability of Systems

- Equilibrium - dynamic state in which system is changing little over time (homeostasis)
- Disturbance - periodic destructive events such as fire or flood
- Resilience - ability of system to recover quickly from disturbance
- State Shift –a severe disturbance in which the system does not return to normal but instead changes some of its state variables.
- *Note: Negative Feedback helps to maintain stability in systems*

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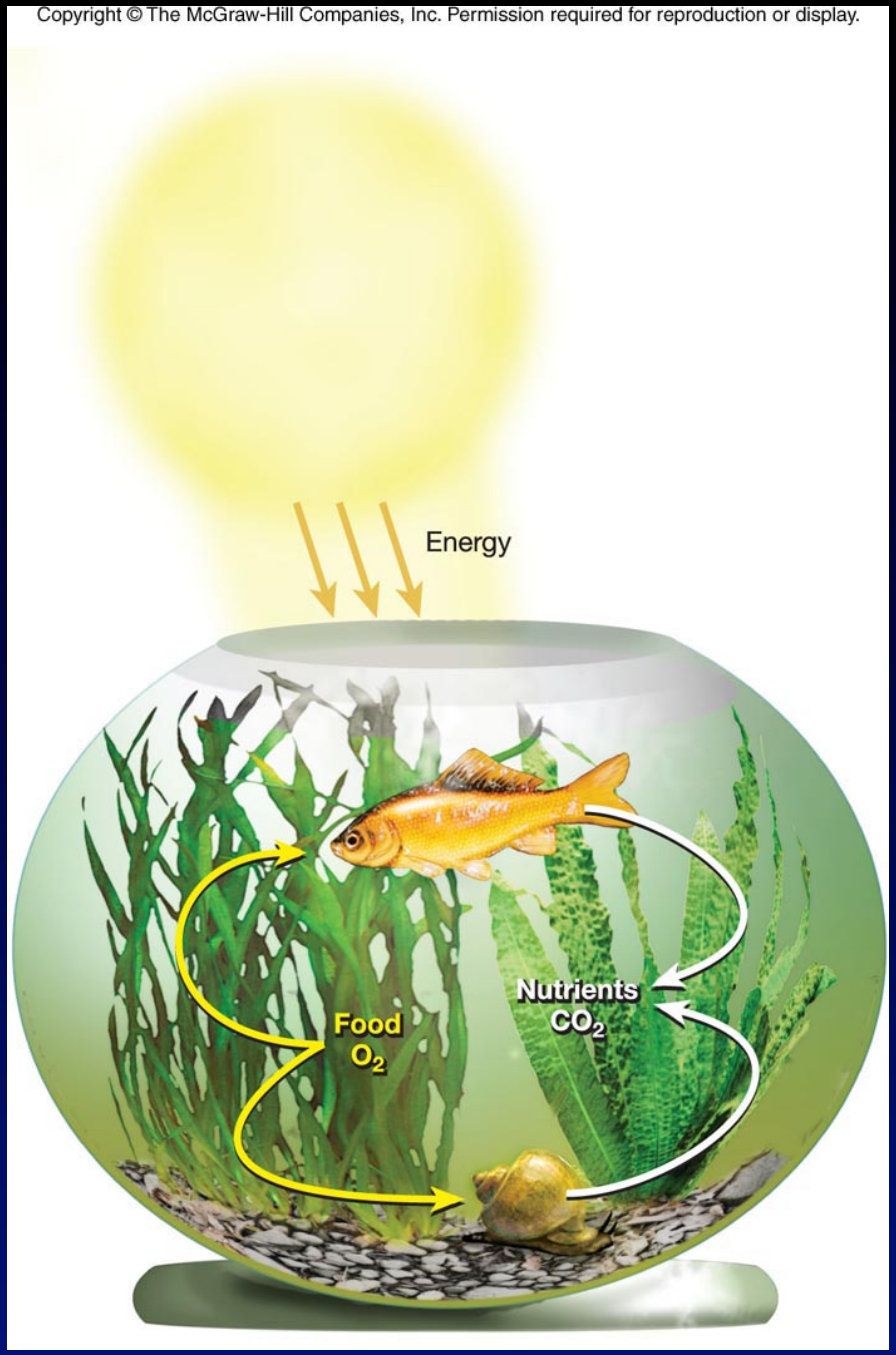

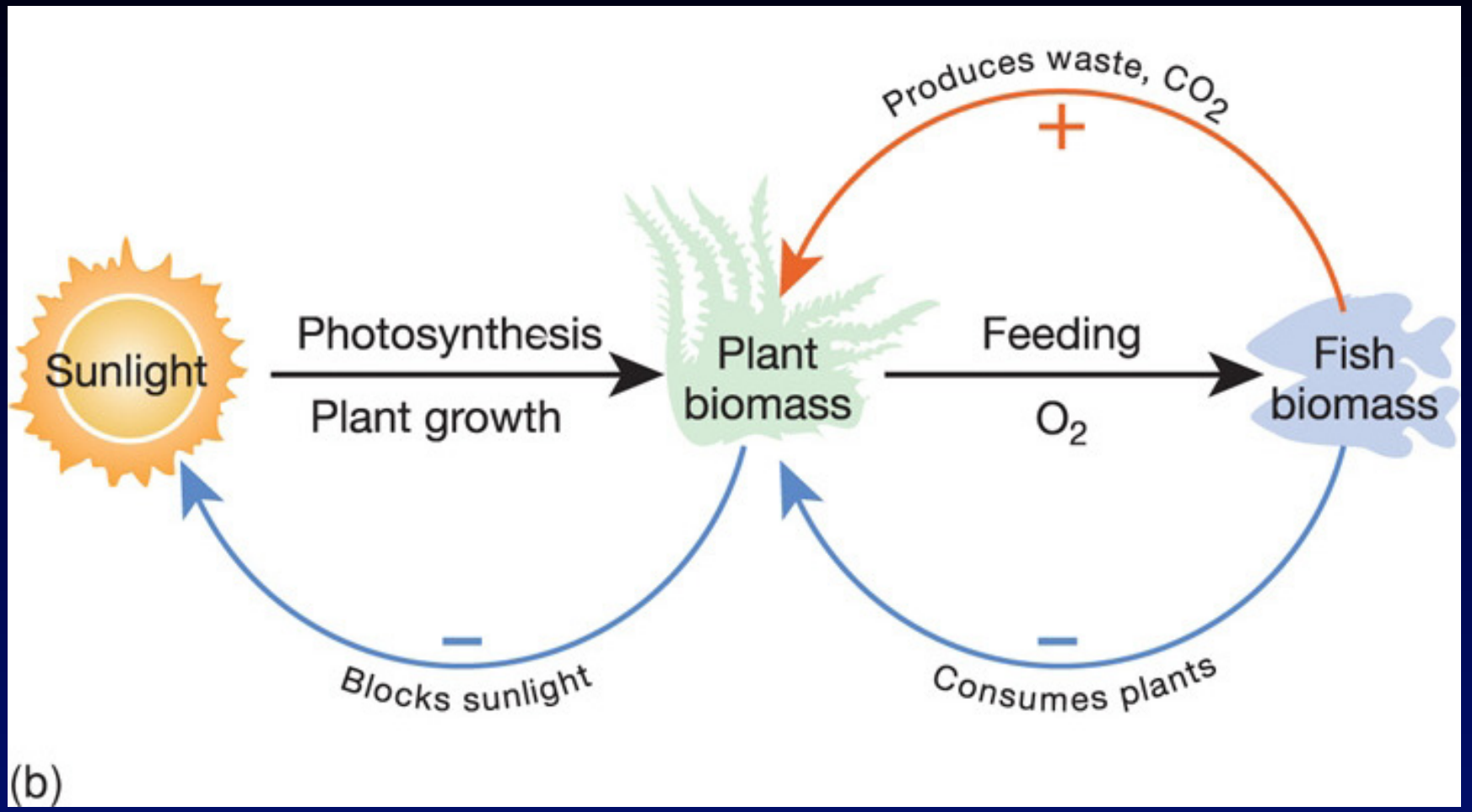
Produces waste, CO_2
+
Sunlight
Photosynthesis
Plant growth
Plant biomass
Feeding
O_2
Fish biomass
−
Blocks sunlight
−
Consumes plants
(b)

System Characteristics

- Emergent properties - characteristics of a whole, functioning system that are quantitatively or qualitatively greater than the sum of the system's parts
  - Example: The human body is a system of flows and compartments but from that system emerge emotions, ideas, painting, dance, etc.

Consensus and Conflict

- Scientific consensus (general agreement among informed scholars) stems from a community of scientists who collaborate in a cumulative, self-correcting process.

- Paradigm shifts (great changes in explanatory frameworks) occur when a majority of scientists agree that an old explanation no longer works very well.

Recognizing Pseudoscience

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TABLE 2.2

Questions for Baloney Detection

1. How reliable are the sources of this claim? Is there reason to believe that they might have an agenda to pursue in this case?
2. Have the claims been verified by other sources? What data are presented in support of this opinion?
3. What position does the majority of the scientific community hold in this issue?
4. How does this claim fit with what we know about how the world works? Is this a reasonable assertion or does it contradict established theories?
5. Are the arguments balanced and logical? Have proponents of a particular position considered alternate points of view or only selected supportive evidence for their particular beliefs?
6. What do you know about the sources of funding for a particular position? Are they financed by groups with partisan goals?
7. Where was evidence for competing theories published? Has it undergone impartial peer review or it is only in proprietary publication?

Environmental Science vs. Environmentalism

- Environmental science - use of scientific method to study processes and systems in the environment
- Environmentalism - working to influence attitudes and policies that affect our environment